# NATIONAL JUNIOR COLLEGE SH2 PRELIMINARY EXAMINATION Higher 2

CANDIDATE NAME

SUBJECT CLASS REGISTRATION NUMBER

## CHEMISTRY

Paper 1 Multiple Choice

9729/01 14 September 2023 1 hour

Additional Materials: Optical Answer Sheet Data Booklet

## READ THESE INSTRUCTIONS FIRST

Write in soft pencil.

Do not use staples, paper clips, glue or correction fluid.

Write your name, subject class and registration number on the Answer Sheet in the spaces provided unless this has been done for you.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.

Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

#### Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer. Any rough working should be done in this booklet.

The use of an approved scientific calculator is expected, where appropriate. A Data Booklet is provided.

#### Instructions on how to fill in the Optical Mark Sheet

Shade the index number in a 5 digit format on the optical mark sheet:  $2^{nd}$  digit and the last 4 digits of the Registration Number.

Example:

Student	Examples of Registration No.	Shade:
	2 <u>2</u> 0 <u>5648</u>	25648

1 Use of the Data Booklet is relevant to this question.

Which particle has more protons than electrons and more protons than neutrons? (D =  ${}^{2}_{1}H$ )

**A**  $D_3O^+$  **B**  $H_3O^+$  **C**  $NH_2^-$  **D**  $OD^-$ 

Ans: (B)

Particle	No of Protons	No of Neutrons	No of Electrons
$D_3O^+$	11	11	10
H <sub>3</sub> O⁺	11	8	10
NH <sub>2</sub> <sup>-</sup>	9	7	10
OD-	9	9	10

\*Only cations have more protons than electrons \*D atom has 1 proton and 1 neutron while H atom has 1 proton and 0 neutron.

**2**  $Cl_2$  reacts with hot dilute NaOH to give  $Cl^-$  and  $ClO_x^-$  in a 5:1 ratio.

What is the value of x in  $ClO_x^-$ ?

A 1 B 2 C 3 D 5 Ans: (C) [R]  $\frac{1}{2}Cl_2 + e^- \longrightarrow Cl^- \dots x5$ [O]  $\frac{1}{2}Cl_2 \longrightarrow ClO_x^- + ne^-$ 

When 5 moles of  $Cl^-$  is produced, 5 moles of electrons are gained. Hence, when 1 mole of  $ClO_x^-$  is produced, 5 moles of electrons are lost. Oxidation state of Cl increased by 5 units, from 0 (in  $Cl_2$ ) to +5 (in  $ClO_x^-$ )

Hence, x = 3

Which statement is a correct explanation of this?

Α Each hydrogen bond formed between water molecules is stronger than that formed between HF molecules.

3

- В There are more atoms in a water molecule than there are in an HF molecule, resulting in stronger intermolecular forces in water.
- С There are on average, more hydrogen bonds between water molecules than there are between HF molecules.
- D The water molecule has stronger permanent dipole-permanent dipole interactions than the HF molecule.

#### Ans: (C)

Both HF and H<sub>2</sub>O are simple covalent molecules and their boiling points are affected by the intermolecular forces between its molecules.

Both HF and H<sub>2</sub>O are able to form hydrogen bonds between its molecules. H-F bond is more polar than H-O bond, hence each hydrogen bond between HF is stronger than that between H<sub>2</sub>O (option A is incorrect).

HF and H<sub>2</sub>O can form different number of H-bonds per molecule. The greater average number of H-bonds formed per molecule

- the more extensive the H-bonds present in the compound
  - •
  - the higher the energy required to break the larger number of H-bonds
  - the higher the boiling point •

	HF	H <sub>2</sub> O
No. of protonic H	1	2
No. of lone pair electrons	3	2
Average no. of H-bonds per molecule	1	2

4 When the carbon-oxygen bonds in methanol,  $CH_3OH$ , methanal, HCHO, and methanoate, HCO<sub>2</sub><sup>-</sup> are arranged in order of increasing length, what is the correct order?

A  $CH_3OH$ ,  $HCO_2^-$ , HCHO

- В  $HCO_2^{-}CH_3OH$ , HCHO
- С HCHO, HCO<sub>2</sub><sup>-</sup>,CH<sub>3</sub>OH
- HCO<sub>2</sub><sup>-</sup>, HCHO, CH<sub>3</sub>OH D

Ans: (C)

HCHO, = double bond  $HCO_2^-$  = partial double bond  $CH_3OH = single bond$ 

Single bond longer than double bond Double bond longer than partial double bond



What are the bond angles x, y and z in histamine, from the smallest to the largest?

	smallest bond angle		largest bond angle
Α	Х	У	Z
В	У	х	Z
С	У	z	х
D	Z	v	х

#### Ans: (A)

x: 3 bond pair regions, 1 lone pair region (trigonal pyramidal), 107°
y: 4 bond pair regions (tetrahedral), 109.5°
z: 3 bond pair regions (trigonal planar), 120°

**6** When a sample of a gas is compressed at constant temperature from 1500 kPa to 6000 kPa, its volume changes from 76.0 cm<sup>3</sup> to 20.5 cm<sup>3</sup>.

Which statements are possible explanations for this behaviour?

- 1 The gas behaves non-ideally.
- 2 The gas partially liquefies.
- 3 The gas molecules have undergone dimerisation.

A 1, 2 and 3 B 1 and 2 only C 2 and 3 only D 1 only

Ans: (D)

Under a fourfold increase in pressure, the volume of an ideal gas will decrease from 76.0 cm<sup>3</sup> to 19.0 cm<sup>3</sup>

Option 1 is correct. The change in volume is not inversely proportional to the increase in pressure (pV = nRT), hence the gas behaves non-ideally.

Option 2 is incorrect. If the gas partially liquefies, the amount of gas molecules would decrease and thus the volume would be much smaller than 19.0 cm<sup>3</sup>.

Option 3 is incorrect. If the gas molecules have undergone dimerization, the amount of gas molecules would decrease and thus the volume would be much smaller than 19.0 cm<sup>3</sup>.

7 The table below describes some of the chemistry and thermodynamic properties of the halogens.

process	name and symbol of quantity
$2HX(g) \longrightarrow H_2(g) + X_2(g)$	enthalpy change of reaction, $\Delta H^{\circ}$
$H_2(g) + X_2(g) \implies 2HX(g)$	equilibrium constant, $K_p$
$X(g) \longrightarrow X^+(g) + e^-$	ionisation energy, I.E.

Which statements are correct?

1  $|\Delta H^{e}|$  for HCl >  $|\Delta H^{e}|$  for HBr

2  $K_{\rm p}$  for HBr >  $K_{\rm p}$  for HI

**3** I.E. for I > I.E. for Cl

A 1, 2 and 3 B 1 and 2 only C 2 and 3 only D 1 only

Ans: (B)

Option 1 is correct: H-C*l* bond energy is 431 versus H-Br bond energy is 366.

Option 2 is correct: H-I bond energy is 299 versus H-Br bond energy is 366, therefore more HBr will be formed as more energy is released. Since  $K_p = (P_{HX})/(P_{H2})(P_{X2})$ , a greater proportion of HX will result in a larger  $K_p$  value.

Option 3 is incorrect. First IE of I is 1010 kJ mol<sup>-1</sup> and first IE of Cl is 1260 kJ mol<sup>-1</sup>

8 In a calorimetric experiment 1.60 g of a fuel are burnt. 45.0 % of the energy released is absorbed by 200 g of water. The temperature of the water rises from 18 °C to 66 °C.

What is the total energy released per gram of fuel burnt (to 3 significant figures)?

**A** 25 100 J **B** 55 700 J **C** 89 200 J **D** 373 000 J

Ans: (B)

Energy required =  $mc\Delta T \times \frac{100}{45}$ = 200 × 4.18 × (66 - 18) ×  $\frac{100}{45}$ = 89 173J

Total energy released per gram of fuel =  $89\ 173 \div 1.6$ =  $55\ 733\ J$ =  $55\ 700\ J\ (3\ sf)$  9 Consider this gas phase reaction.

 $Cl_2(g) + CHCl_3(g) \longrightarrow HCl(g) + CCl_4(g)$ 

The rate equation for the above reaction is given below.

rate =  $k [CHCl_3] [Cl_2]^{1/2}$ 

Based on this information, what conclusions can be drawn about this proposed mechanism?

Step 1  $Cl_2(g) \rightleftharpoons 2Cl(g)$ 

Step 2  $Cl(g) + CHCl_3(g) \longrightarrow HCl(g) + CCl_3(g)$ 

Step 3  $Cl(g) + CCl_3(g) \longrightarrow CCl_4(g)$ 

- A Step 1 is the rate-determining step.
- **B** Step **2** is the rate-determining step.
- **C** Step **3** is the rate-determining step.
- **D** The rate-determining step cannot be identified.

Ans: (B)

In step 1,  $K_c = \frac{[Cl]^2}{[Cl_2]}$ 

 $[Cl] = K_c^{1/2} [Cl_2]^{1/2}$ 

When step 2 is the rate-determining step, rate = k [Cl] [CHCl<sub>3</sub>] = k ×  $K_c^{1/2}$  [Cl<sub>2</sub>]<sup>1/2</sup> [CHCl<sub>3</sub>] = k' [Cl<sub>2</sub>]<sup>1/2</sup> [CHCl<sub>3</sub>] **10** Ethyl ethanoate undergoes acid-catalysed hydrolysis in water where the concentration of acid in the solution remains constant.

$$CH_{3}CO_{2}CH_{2}CH_{3} + H_{2}O \xrightarrow{H^{+}} CH_{3}CO_{2}H + CH_{3}CH_{2}OH$$

The rate equation is found to be rate =  $k[CH_3CO_2CH_2CH_3][H^+]$ 

In an experiment, when 1.0 mol dm<sup>-3</sup> HCl was reacted with 0.20 mol dm<sup>-3</sup> ethyl ethanoate, the half-life was found to be 42 min.

In a second experiment, 1.0 mol dm<sup>-3</sup> HC*l* was reacted with 0.10 mol dm<sup>-3</sup> ethyl ethanoate.

What is the half-life of the second experiment?

**A** 10.5 min **B** 21 min **C** 42 min **D** 84 min

#### Ans: (C)

**11** The equation below shows the reaction of ethanoic acid with ethanol.

$$CH_3CO_2H(l) + CH_3CH_2OH(l) \implies CH_3CO_2CH_2CH_3(l) + H_2O(l)$$
  
ethyl ethanoate

Which statement is true when the above reaction has attained equilibrium?

- **A** The equilibrium constant, *K*, is equal to 1.
- **B** The reaction between the acid and the alcohol has stopped.
- **C** The concentrations of the products and reactants are the same.
- **D** The rate of formation and the rate of hydrolysis of ethyl ethanoate are the same.

#### Ans: (D)

At equilibrium, the reactants react continually to form ester while the ester continually hydrolyse to form the reactants at the same rate; thus option **B** is wrong and **D** is true.

The value of equilibrium constant, K, (i.e. ratio of concentrations of reactants and concentrations of products raised to appropriate power terms as the stoichiometric ratio) varies from system to system and cannot be predicted; thus option **A** and option **C** may not be true all the time.

- 12 Which statements regarding acids and bases are correct?
  - 1 Water can act as either an acid or a base.
  - **2** When  $A/Cl_3$  reacts with  $Cl_2$ , the  $A/Cl_3$  acts as a Lewis acid.
  - 3 The ammonium ion acts as a base when reacted with hydroxide ions.

A 1, 2 and 3 B 1 and 2 only C 2 and 3 only D 1 only

Ans: (B)

Option 1 is correct:  $CH_3COOH + H_2O \implies CH_3COO^- + H_3O^+$  $NH_3 + H_2O \implies NH_4^+ + OH^-$ 

Option 2 is correct:  $AlCl_3$  reacts with  $Cl_2$  to form  $AlCl_4^-$  and  $Cl^+$ . The Al in  $AlCl_3$  acts as an electron pair acceptor.

Option 3 is incorrect: Ammonium ion acts as an acid to donate H<sup>+</sup> to OH<sup>-</sup> to form H<sub>2</sub>O. NH<sub>4</sub><sup>+</sup> + OH<sup>-</sup>  $\rightarrow$  NH<sub>3</sub> + H<sub>2</sub>O

**13** A 1 dm<sup>3</sup> solution was made by mixing  $4.0 \times 10^{-8}$  mol of HC*l*(aq) and  $2.5 \times 10^{-8}$  mol of NaOH(aq).

What is the pH of the resulting solution?

<b>A</b> 0.18 <b>B</b> 6.94 <b>C</b> 7.00 <b>D</b>	7.82
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Ans: (B)

	HC <i>l</i>	+ NaOH	$\longrightarrow$	NaC <i>l</i>	+ H <sub>2</sub> O
Initial / mol	4.0 × 10 <sup>-8</sup>	2.5 × 10 <sup>−8</sup> (L.R.)		0	Ι
Change / mol	-2.5 × 10 <sup>-8</sup>	-2.5 × 10 <sup>-8</sup>		+2.5 × 10 <sup>-8</sup>	Ι
Final / mol	$1.5  imes 10^{-8}$	0		$2.5  imes 10^{-8}$	-

[unreacted HCl] =  $1.5 \times 10^{-8}$  mol dm<sup>-3</sup>

Since contribution of H<sup>+</sup> from HCl <  $10^{-7}$  mol dm<sup>-3</sup> from H<sub>2</sub>O, pH = -lg[H<sup>+</sup>] = -lg( $1.5 \times 10^{-8} + 10^{-7}$ ) = 6.94 **14** A mixture consists of 0.10 mol dm<sup>-3</sup> MgSO<sub>4</sub> and 0.10 mol dm<sup>-3</sup> FeSO<sub>4</sub>. It is suggested that the metal ions can be separated as their hydroxides by adding solid NaOH to the mixture.

At 298 K, the solubility product of Mg(OH)<sub>2</sub> is  $7.1 \times 10^{-12}$  mol<sup>3</sup> dm<sup>-9</sup> and that of Fe(OH)<sub>2</sub> is  $4.1 \times 10^{-15}$  mol<sup>3</sup> dm<sup>-9</sup>.

What would be the pH of the resultant solution when maximum separation has occurred?

**A** 5.07 **B** 7.30 **C** 8.93 **D** 10.10

Ans: (C)

Since Mg(OH)<sub>2</sub> and Fe(OH)<sub>2</sub> have the same formula type, Fe(OH)<sub>2</sub> is less soluble than Mg(OH)<sub>2</sub> due to the smaller  $K_{SP}$  value. Hence, Fe(OH)<sub>2</sub> will precipitate out first as NaOH(aq) is added.

The maximum separation will occur, just before Mg(OH)<sub>2</sub> is precipitated.

Hence,  $K_{sp}$  of Mg(OH)<sub>2</sub> = IP of Mg(OH)<sub>2</sub> 7.1 × 10<sup>-12</sup> = [Mg<sup>2+</sup>] [OH<sup>-</sup>]<sup>2</sup> = (0.10) [OH<sup>-</sup>]<sup>2</sup> [OH<sup>-</sup>] = 8.426 × 10<sup>-6</sup> mol dm<sup>-3</sup>

 $pOH = -lg (8.426 \times 10^{-6})$ = 5.07

pH = 14 - 5.07 = 8.93

**15 W**, **X** and **Y** are elements in Period 3 of the Periodic Table.

A mixture containing the oxides of W, X and Y was dissolved in excess dilute sulfuric acid and filtered. The oxide of Y was collected as a residue.

When excess dilute sodium hydroxide was added to the filtrate, only a white precipitate of the hydroxide of  $\mathbf{X}$  was formed.

What are the possible identities of **W**, **X** and **Y**?

	W	Х	Y
Α	Mg	Al	Р
В	Al	Mg	Р
С	Mg	Al	Si
D	Al	Mg	Si

Ans: (D)

MgO,  $Al_2O_3$  react with dilute sulfuric acid to give MgSO<sub>4</sub>(aq) and  $Al_2(SO_4)_3(aq)$  respectively.

 $P_4O_{10}$  reacts with water to give  $H_3PO_4(aq)$ .

 $SiO_2$  does not react with acid and does not dissolve in water and is thus collected as the residue. Therefore, **Y** is Si.

Filtrate contains  $Mg^{2+}$  or  $Al^{3+}$ . When excess NaOH is added to the filtrate,  $Mg(OH)_2$  is formed as white ppt. Thus, **X** is Mg.

 $Al^{3+}$  reacts with NaOH(aq) to give white ppt  $Al(OH)_3$  which is amphoteric and will react with excess NaOH(aq) to form colourless solution NaA $l(OH)_4$  containing the complex ion  $[Al(OH)_4]^-$ .

 $Al(OH)_3(s) + NaOH(aq) \rightarrow NaAl(OH)_4(aq)$ Thus, **W** is Al. 16 The graph below shows the trend for a property of X, Y and Z.



Which property about X, Y and Z will give the trend shown above?

	Property	Х	Y	Z
Α	pH of the resultant solution when added to water	MgCl <sub>2</sub>	AlCl <sub>3</sub>	SiCl <sub>4</sub>
в	Decomposition temperature	MgCO <sub>3</sub>	CaCO <sub>3</sub>	SrCO <sub>3</sub>
С	Boiling point	HC <i>l</i>	HBr	HI
D	First ionization energy	Mg	Al	Si

#### Ans: (A)

Option **A** is correct: pH of MgC $l_2$ , AlC $l_3$ , SiC $l_4$  in water are 6.5, 3 and 1 respectively.

Option **B** is incorrect: Thermal stability of Grp 2 carbonates increases down the group, thus, decomposition temperature increases down the group. Down the group, charge/size ratio of cation decreases, polarizing power decreases, extent of distortion of electron cloud of carbonate decreases, C-O bond is weakened to a lesser extent, resulting in more energy required to break the C-O bond in carbonate down Group 2.

Option **C** is incorrect: Boiling point increases from HCl to HI as size of electron cloud increases, dipoles are more easily induced, leading to stronger instantaneous dipole-induced dipole (id-id) interactions. Hence more energy is required to overcome the strongest id-id between HI molecules, thus highest boiling point.

Option **D** is incorrect: Electronic configuration of Mg: [Ne]3s<sup>2</sup> Electronic configuration of A*l*: [Ne]3s<sup>2</sup>3p<sup>1</sup> Electronic configuration of Si: [Ne]3s<sup>2</sup>3p<sup>2</sup>

The most loosely held electron is in the higher energy 3p subshell in A*l* while that of Mg is in the 3s subshell. Less energy is required to remove the most loosely held electron in A*l* than Mg. Comparing A*l* and Si, Si has higher nuclear charge and similar shielding effect as A*l*, hence nuclear attraction is higher for Si, more energy is required to remove the most loosely held electron in Si. 17 An element X and compound YZ react separately with acid as shown.

$$\begin{split} \boldsymbol{X}(s) + 2H^{*}(aq) &\longrightarrow \boldsymbol{X}^{2*}(aq) + H_{2}(g) \\ \boldsymbol{Y}\boldsymbol{Z}(s) + 2H^{*}(aq) &\longrightarrow \boldsymbol{Y}^{2*}(aq) + H_{2}\boldsymbol{Z}(g) \end{split}$$

When 1.0 g of either X or YZ is reacted with an excess of acid, the total volume of gas formed is the same.

Which statements are correct?

1 
$$A_r(\mathbf{X}) = M_r(\mathbf{Y}\mathbf{Z})$$

2 X and Y are metals.

A 1, 2 and 3 B 1 and 2 only C 2 and 3 only D 1 only

#### Ans: (B)

1. This statement is correct as the number of moles of X(s) and YZ(s) are the same as the total volume of gas formed is the same. (moles = mass/ $A_r$  or  $M_r$ ).

2. X is a reactive metal that reacts with acid. Y is a metal as it forms positive ion upon reaction with an acid.

3. This statement is incorrect, **X** and **Y** could be in Group 2, or one or both of them could be transition metals.

**18** Use of the Data Booklet is relevant to this question.



The following conclusions were made based on the set up as shown above.

Which statement is correct?

- A Zn is the positive electrode while Pb is the negative electrode.
- **B** Chlorine gas is produced at the Zn electrode.
- **C** The voltmeter will show a reading of 0.63V.
- **D** When H<sub>2</sub>SO<sub>4</sub>(aq) is added to the beaker containing Pb(NO<sub>3</sub>)<sub>2</sub>, the voltmeter reading becomes smaller.

#### Ans: (D)

 $\begin{array}{lll} Pb^{2+}+2e^{-} & \Longrightarrow & Pb & E^{\circ}=-0.13 \ V\\ Zn^{2+}+2e^{-} & \rightleftarrows & Zn & E^{\circ}=-0.76 \ V\\ Pb^{2+}/Pb \ half-cell \ undergoes \ reduction \ while \ Zn^{2+}/Zn \ half-cell \ undergoes \ oxidation.\\ E^{\circ}_{cell} = -0.13 - (-0.76) = + \ 0.63 \ V\\ under \ standard \ conditions \ of 1 \ mol \ dm^{-3}, \ 298 \ K \ and 1 \ bar \end{array}$ 

Option A is **incorrect**. The electrochemical cell functions as a battery. The Zn electrode releases electron to the external circuit and is the negative electrode.

Option B is incorrect. In the Zn<sup>2+</sup>/Zn half-cell, oxidation of Zn  $\longrightarrow$  Zn<sup>2+</sup> + 2e<sup>-</sup> occurs. Oxidation of Cl<sup>-</sup> to Cl<sub>2</sub> would require electrolysis (external battery) AND high concentration of Cl<sup>-</sup>.

Option C is incorrect. This set up is not under standard condition, concentration of  $Zn^{2+}$  is not 1 mol dm<sup>-3</sup>. The E<sub>cell</sub> value will be different from +0.63V.

Option D is correct.  $SO_4^{2^-}(aq) + Pb^{2^+}(aq) \longrightarrow PbSO_4$  (s). This decreases  $[Pb^{2^+}(aq)]$  and cause the POE of  $Pb^{2^+} + 2e^- \Longrightarrow Pb$  to shift to the left.  $E(Pb^{2^+}/Pb)$  is more negative and since  $E^{\circ}_{cell} = E(Pb^{2^+}/Pb) - E(Zn^{2^+}/Zn)$ ,  $E_{cell}$  will be smaller than +0.63V.

**19** The use of Data Booklet is relevant to this question.

A piece of copper, containing impurities of zinc and silver metal, was purified via electrolysis.

Which statement is correct about the process?

- **A** The concentration of  $Cu^{2+}$  in the electrolyte has to be at 1 mol dm<sup>-3</sup>.
- **B** The impure copper is placed at the positive terminal.
- **C** Silver metal is oxidized at the anode.
- **D**  $Zn^{2+}$  is reduced at the cathode.

#### Ans: (B)

Option A is incorrect: Concentration of  $Cu^{2+}$  does not have to be at 1 mol dm<sup>-3</sup> for purification of metal.

Option B is correct: The impure copper has to be placed at the positively charged anode so that the metals can be oxidised to their cations.

Option C is incorrect: Silver metal is not oxidised as  $E(Ag^+/Ag)$  is more positive than  $E(Cu^{2+}/Cu)$ , hence copper solid is oxidized first.

Option D is incorrect: Zinc cation is not reduced at the cathode as  $E(Zn^{2+}/Zn)$  is less positive than  $E(Cu^{2+}/Cu)$ , hence  $Cu^{2+}$  is reduced at the cathode.

20 Which statement about the reaction below is true?

$$[Fe(EDTA)]^{-} + 3C_2O_4^{2-} \implies [Fe(C_2O_4)_3]^{3-} + EDTA^{4-}$$
   
*K*<sub>c</sub> value = 3 × 10<sup>-21</sup>

- **A** It is a redox reaction.
- **B** The  $C_2O_4^{2-}$  ligand has a greater binding affinity than EDTA<sup>4-</sup> ligand to the iron ion.
- **C** The reaction is less feasible at high temperatures.
- **D** The coordination numbers of  $[Fe(EDTA)]^-$  and  $[Fe(C_2O_4)_3]^{3-}$  are 6 and 3 respectively.

#### Ans: (C)

Statement **A** is incorrect. Oxidation number of Fe remains constant at +3 in both complexes. This is a ligand exchange reaction instead of redox.

Statement **B** is incorrect. From the extremely small value of  $K_c$  given, it shows that equilibrium position lies largely on the left, showing that EDTA<sup>4–</sup> has a greater binding affinity than  $C_2O_4^{2-}$ .

Statement **C** is correct.  $\Delta$ S is negative as the amount of molecules in the aqueous state decreases from 4 to 2.

For a reaction to be feasible,  $\Delta G$  must be < 0, i.e.  $\Delta H - T\Delta S < 0$ 

 $\Delta H < T \Delta S$ 

Only at low T, T $\Delta$ S is more than  $\Delta$ H, reaction is feasible. Hence, statement **C** is correct, the reaction is less feasible at high temperatures.

Statement **D** is incorrect. EDTA<sup>4–</sup> is a hexadentate ligand, coordination number of  $[Fe(EDTA)]^{-}$  is 6. However,  $C_2O_4^{2-}$  is a bidentate ligand, i.e. each ligand forms two dative bonds with Fe<sup>3+</sup>, hence, the co-ordination number of  $[Fe(C_2O_4)_3]^{3-}$  is also 6.

21 How many stereoisomers are possible for the following compound?



There are 7 chiral carbons in compound. There is no C=C that can display cis-trans isomerism.

Maximum number of stereoisomers =  $2^{n+m} = 2^{7+0}$ 

L HO

**22** The energy profile diagram shown below corresponds to one of the steps in the reaction mechanism of ethane with bromine in the presence of UV light.



To which step does this diagram apply?

- **A**  $CH_3\dot{C}H_2 + CH_3\dot{C}H_2 \longrightarrow CH_3CH_2CH_2CH_3$
- $\textbf{C} \quad CH_3 \overset{\bullet}{C}H_2 + Br \bullet \longrightarrow CH_3 CH_2 Br$
- $\mathbf{D} \quad \mathsf{Br}_2 \longrightarrow \ \mathsf{Br}^\bullet + \ \mathsf{Br}^\bullet$

#### Ans: (D)

Energy profile diagram indicates an endothermic reaction in the single reaction step. Hence, option D is correct as  $Br_2$  takes in energy to undergo bond breaking (endothermic) to give 2 Br radicals.

Option A and C are incorrect as only bond formation occurs, energy is given off (exothermic).

Option B is incorrect, there is bond breaking of Br–Br (193 kJ mol<sup>-1</sup>) followed by bond formation of C–Br (280 kJ mol<sup>-1</sup>), overall exothermic.

23 Some dichlorobutanes were separately treated with hot ethanolic sodium hydroxide. The formula of the hydrocarbon formed is  $C_4H_6$ .

Which pair of dichlorobutane can form the same hydrocarbon, C<sub>4</sub>H<sub>6</sub>?

- 1  $CH_2ClC(CH_3)_2Cl$
- 2 CH<sub>3</sub>CHC*l*CHC*l*CH<sub>3</sub>
- $3 \qquad CH_2ClCH_2CH_2CH_2Cl$
- 4  $CH_3CH_2CH_2CHCl_2$

A 1	and <b>2</b>	В	1 and 4	С	2 and 3	D	2 and 4
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Ans: (C)

Option 1:  $CH_2C/C(CH_3)=CH_2$  cannot lose  $2^{nd}$  pair of HCl as adjacent C to the C with Cl does not have a H for elimination

Option 2:  $CH_3CHC/CHC/CH_3 \longrightarrow CH_2=CHCH=CH_2$ Buta-1,3-diene

Option 3:  $CH_2ClCH_2CH_2CH_2Cl \longrightarrow CH_2=CHCH=CH_2$ Buta-1,3-diene

Option 4:  $CH_3CH_2CH_2CHCl_2 \longrightarrow CH_3CH_2CH=CHCl$  or  $CH_3CH_2C\equiv CH$ 

24 Compound X has the following structure.



compound  ${f X}$ 

It can be synthesised by reacting ammonia with a halogenoalkane.

Which statements are correct?



- 2 Synthesis of Compound X involves intramolecular nucleophilic substitution.
- 3 Compound X is formed at the same rate regardless of the halogen present in the halogenoalkane.
- A 1 only B 1 and 2 only C 2 and 3 only D 1, 2 and 3

#### Ans: (B)

Statements 1 and 2 are correct: This halogenoalkane will form the compound X via intramolecular nucleophilic substitution to form the tertiary amine due to the presence of the 3 RX functional group.



Statement 3 is **incorrect**: The rate of reaction of Nucleophilic sub reaction is dependent on the bond strength of the C-X bond. Hence it does not happen at the same rate.

25 A manufacturer wishes to make methyl salicylate, the aromatic liniment of oil of wintergreen, from salicylic acid.



How is this esterification of salicylic acid best achieved?

- A Addition of cold ethanoyl chloride.
- **B** Heat with methanol.
- **C** Heat with methanol and sulfuric acid.
- D Heat with ethanoic acid and sulfuric acid.

#### Ans: (C)

Esterification of the carboxylic acid group requires methanol, concentrated H<sub>2</sub>SO<sub>4</sub> and heat.

**26** Tartaric acid, a common acid, has the following structure below.



Which reagent reacts in stoichiometric ratio with 1 mol of tartaric acid in a complete reaction?

- A 4 mol of Na
- B 2 mol of Na<sub>2</sub>CO<sub>3</sub>
- C 2 mol of SOCl<sub>2</sub>
- D 4 mol of aqueous KOH
- Ans: (A)

Option A is correct. All 4 alcohol and carboxylic acid functional groups are all able to react with Na.

Option B is incorrect. Only the 2 carboxylic acid functional groups are all able to react with Na<sub>2</sub>CO<sub>3</sub>. One mole of tartaric acid will provide 2 moles of H<sup>+</sup> to react with 1 mole of Na<sub>2</sub>CO<sub>3</sub>.  $CO_3^{2^-} + 2H^+ \longrightarrow CO_2 + H_2O$ 

Option C is incorrect. All 4 alcohol and carboxylic acid functional groups are all able to react with SOC*l*<sub>2</sub> to form RC*l* and RCOC*l* respectively.

Option D is incorrect. Only the 2 carboxylic acid functional groups are able to react with KOH.

# **27** Compound **X** has molecular formula C<sub>4</sub>H<sub>10</sub>O. Separate samples of **X** are tested with three different reagents.

Which results could **not** be obtained?

	Tollens' reagent	2, 4-dinitrophenylhydrazine	warm acidified potassium
	9	reagent	dichromate (VI) solution
1	silver mirror forms	orange precipitate forms	orange to green
2	no change	no change	no change
3	no change	no change	orange to green
A 1,	2 and 3 B 1	and 2 only C 2 and 3 c	only <b>D 1</b> only

# Ans : (D)

Option 1 could not be obtained. Compound X, whose formula is  $C_4H_{10}O$ , cannot be an aldehyde.

Option 2 could be obtained.  $C_4H_{10}O$  may be a tertiary alcohol.

Option 3 could be obtained.  $C_4H_{10}O$  may be a primary and secondary alcohol.

28 Which reagents and conditions can be used to distinguish the compounds in each pair?

	compound 1	compound 2	Reagents and conditions			
Α	<b>H</b>	HN	$Br_2(aq)$ , room temperature			
в	CH <sub>3</sub> CH <sub>2</sub> COCI <sub>3</sub>	CH <sub>3</sub> CH(OH)CH <sub>2</sub> CH <sub>3</sub>	I₂(aq), NaOH(aq), warm			
С	0	ΟΟΟ	alkaline Cu <sup>2+</sup> complex, warm			
D	$C_6H_5CH_2CH_3$	$C_6H_5CH=CH_2$	KMnO₄(aq), dilute H₂SO₄, heat			

#### Ans: (C)

Option A is incorrect: Both phenol and phenylamine (compound 2) are able to decolourise Br<sub>2</sub> via electrophilic substitution due to the presence of electron donating groups via resonance.

Option B is incorrect: Both compounds contain the structure to react via the tri-iodomethane test.

Option C is correct: Benzaldehyde (compound 1) cannot react with Fehling's reagent while compound 2 can react with Fehling's reagent.

Option D is **incorrect**: Both compounds' R group attached to the benzene ring is able to oxidise to decolourise purple  $KMnO_4$  and produce effervescence of carbon dioxide.

**29** The structure of caffeine is shown below.



Which statement is correct?

- A Caffeine is soluble in ethanol.
- B Caffeine is neutral.
- **C** Caffeine exists as a zwitterion.
- **D** Caffeine reacts with LiA*l*H<sub>4</sub> to give a product containing secondary alcohol.

#### Ans: (A)

Option A is correct. Strong hydrogen bonds can be formed between alcohol group of ethanol and the lone pair electrons on the N or O atoms in caffeine. Energy released during the formation of these hydrogen bonds is sufficient to compensate for the energy required to overcome the pd-pd and hydrogen bonds between caffeine and water respectively.

Option B is incorrect. The N atom on the right hand side ring is an amine and is basic.

Option C is **incorrect**. No carboxylic acid group is present. Amine group alone cannot form zwitterion.

Option D is incorrect. Amide group undergoes reduction to give amine, NOT alcohol.

**30** The Claisen rearrangement is a powerful carbon–carbon bond-forming chemical reaction. An example of the mechanism is shown below.



What could be the identity of the product formed when the following compound undergoes Claisen rearrangement?











D





1	2	3	4	5	6	7	8	9	10
В	С	С	С	Α	D	В	В	В	С
11	12	13	14	15	16	17	18	19	20
D	В	В	С	D	Α	В	D	В	С
21	22	23	24	25	26	27	28	29	30
В	D	С	В	С	Α	D	С	Α	В